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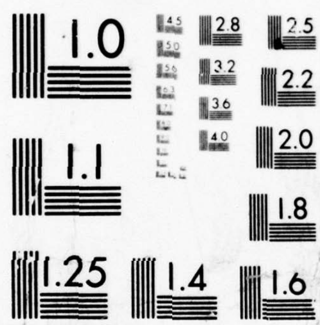

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Display Size and Target Acquisition Performance

by
Michael J. Barnes
Systems Effectiveness Division
Systems Development Department

JANUARY 1978

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Naval Weapons Center
CHINA LAKE, CALIFORNIA 93555

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FOREWORD

A literature review and two experiments on the effects of a number of variables, including display size, upon target acquisition performance were conducted at the Naval Weapons Center between July 1976 and October 1977. This work was performed under a Naval Air Systems Command program on target acquisition and display/control requirements for Navy fighter and attack aircraft under the direction of Cdr. Paul Chatelier (AIR-340F), and was supported by AirTasks A3400000/08B/5F55-525-402 and A03A3400/008B/7F55-525-000.

This report has been reviewed for technical accuracy by Ronald A. Erickson.

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(U) *Display Size and Target Acquisition Performance*, by Michael J. Barnes. China Lake, Calif., Naval Weapons Center, January 1978. 44 pp. (NWC TP 6006, publication UNCLASSIFIED.)

(U) Two experiments were conducted to find factors that have an important effect on display size criteria in a cockpit-display system. Subjects in both experiments detected military targets simulating images from a TV camera looking obliquely forward as it is flown over the terrain.

(U) The results of the two experiments indicated that the physical size of a television monitor is not an important factor if MTF and visual angle are held constant. Of the factors studied, the four most important were: number of targets, visual angle of targets, target contrast, and target configuration.

(U) The data from the second experiment were used to generate a multiple regression model. The relationship between target visual angle and display size allowed the regression model to be used to predict performance as a function of display size.

CONTENTS

INTRODUCTION

The design and layout of an aircraft cockpit requires consideration of the space limitations, display and control technology, the mission of the aircraft, and the associated tasks that the aircrew must perform. Current Navy aircraft use cathode ray tubes (CRTs) to display symbology, as well as real-world imagery from television (TV) or forward-looking infrared systems (FLIRs). The A-7E aircraft has a CRT display for imagery from TV-guided weapons, and the A-7E FLIR system uses the CRT in the head-up display as its monitor. The A-6E aircraft also uses CRTs, and the F-18 now under development uses three CRTs for alphanumeric, symbolic, and FLIR displays.

Whenever the tasks of display design, cockpit layout, or air-to-ground target acquisition with electro-optical sensors arise, the question of display size also comes up. The experiments described in this report were conducted to provide some quantitative answers to this question. The experiments provide results that relate the size of a display to the operator's performance at target acquisition. The results can be used to specify system requirements, or to predict target acquisition performance with existing systems.

OVERVIEW

Two laboratory experiments were conducted in which subjects were required to search a CRT display for military-type targets; under one condition they also simultaneously monitored another display for "malfunction" indications. The display was generated by videotaping the imagery from a realistic terrain model and then playing it back to the subjects. The targets were tanks, missiles, houses, and trucks.

The imagery was similar to that produced by a TV camera looking forward and obliquely downward as it is flown over the terrain.

In the first experiment, eleven factors identified in a literature review were examined using a screening (partial factorial) design. The four most important factors, accounting for 50% of the variance, were then used as the basis for the second experiment which used a full factorial design.

Both an analysis of variance and a regression analysis were performed on the data. A model was generated from the data which predicted performance (percentage correct) for different display sizes under a variety of different conditions. Subject differences were investigated using statistics developed from signal detection theory.

GENERAL EXPERIMENTAL APPROACH

The relationship of display size and human performance is a complex issue when considered in a systems context. For example, an attack aircraft has many system parameters that affect pilot performance. When these vary, the size of the display required also varies. Therefore, the effect of display size on pilot performance should be measured as part of a general empirical model predicting operator performance for a cockpit-display system. The problem with generating such a model is that the number of factors that must be considered is too large to use traditional experimental designs.

The approach used for this study involves a multivariate experimental program.[1] The result of such an approach is a predictive model relating operator performance to a selected subset of system parameters.

The multivariate approach involves more than simply varying a number of arbitrarily chosen variables in the same experiment. Rather, it is a multistage experimental program consisting of three major steps: (1) review of the literature to identify potentially important factors in the system being investigated; (2) choice of 10 or more of these factors to be used in a statistical screening experiment; and (3) the use of traditional experimental designs[2] and multiple regression techniques[3] to generate a mathematical model to predict system performance. At each stage, the number of factors considered is reduced until systems performance is described in terms of a small number of important factors.

---

[1] Hughes Aircraft Co. *Economical Multifactor Designs for Human Factors Engineering Experiments*, by C. W. Simon. Culver City, CA, HAC, June 1973. (Technical Report No. P73-326, publication UNCLASSIFIED.)

[2] Roger E. Kirk. *Experimental Design: Procedures for the Behavioral Sciences*. Belmont, CA, Brooks-Cole, 1968, pp. 171-244.

[3] N. R. Draper and H. Smith. *Applied Regression Analysis*. New York, John Wiley & Sons, 1966.

EXPERIMENT 1

OVERVIEW

The purpose of this experiment was to identify factors which most influenced pilot performance for a detection task. The independent variables, their high and low level values, and the fixed parameters of the experiment are given in Table 1.

TABLE 1. Experiment 1, Fixed Parameters and Independent Variables.

Fixed parameters	Value	Independent variables	High level	Low level
Terrain scale	800:1	Display size	9-inch	2-inch
Altitude	3,200 ft[a]	Visual angle of target	22 min	11 min
Range from sensor to ground at center of FOV	2.6 nmi[a]	Simulated air-speed	259 knots	460 knots
Field of view	2°	Mode of image presentation	Moving or snow plow	Series of stills
Footprint length	925 m	Operator uncertainty	1 bit	2 bits
Footprint width	305 m	Approx. target-background contrast	-0.48	-0.27
Terrain clutter	(European) medium	Signal-to-noise ratio	28 dB	12 dB
Targets	Tank, truck	Television resolution	300 lines	175 lines
	House, missile	Task Load	One display	Three displays
		No. of targets	Six	Three
		Subjects	...	...

[a] Feet and nautical miles, rather than metric terms, are most generally used for altitude and range, respectively.

APPARATUS

Four 525-line TV monitors were used as displays. Either a 2-inch 3Q monitor or a 9-inch Conrac monitor matched for modulation transfer function (MTF) (Appendix A) was centered in a black display console. On either side of the center monitor were two Shibaden 9-inch monitors. Three Ampex videotape recorders (VTRs) provided input for the monitors. The output cable from the VTR to the center monitor was routed through a noise mixer. Noise from a General Radio random noise generator was fed into an SRL model 262 low-pass filter set at 6 MHz. The output from the filter was mixed with the video signal from the VTR and used as the input for the center TV monitor (Figure 1).

A stationary Sony video camera observing a movable terrain model having different medium-clutter scenes provided imagery for the center monitor. One of four targets (missiles, trucks, tanks, and houses), each 1 cm across, was located on the terrain model during target trials. Figure 2 shows a typical scene on the center TV monitor.

A headrest was used to maintain a constant distance between the subject and displays during the experiment. The subject heard the response tone through earphones and used a two-button response box. Signals from the box were fed into a Honeywell visicorder to record responses.

SUBJECTS

Six engineers employed at the Naval Weapons Center were used as subjects. The subjects ranged in age from 30 to 37 years. All subjects tested at least 20/20 (corrected) on a Bausch and Lomb Armed Forces Vision Tester for both far and near binocular visual acuity.

METHODOLOGY

Design

The screening experiment used a saturated fractional-factorial design. Computational procedures, advantages and limitations of such a design are discussed in detail by Simon.[1] Two orthogonal blocks of 16 conditions each (i.e., basic and foldover blocks[1]) were used to estimate the effects of 10 factors and 21 strings of second-order interactions.

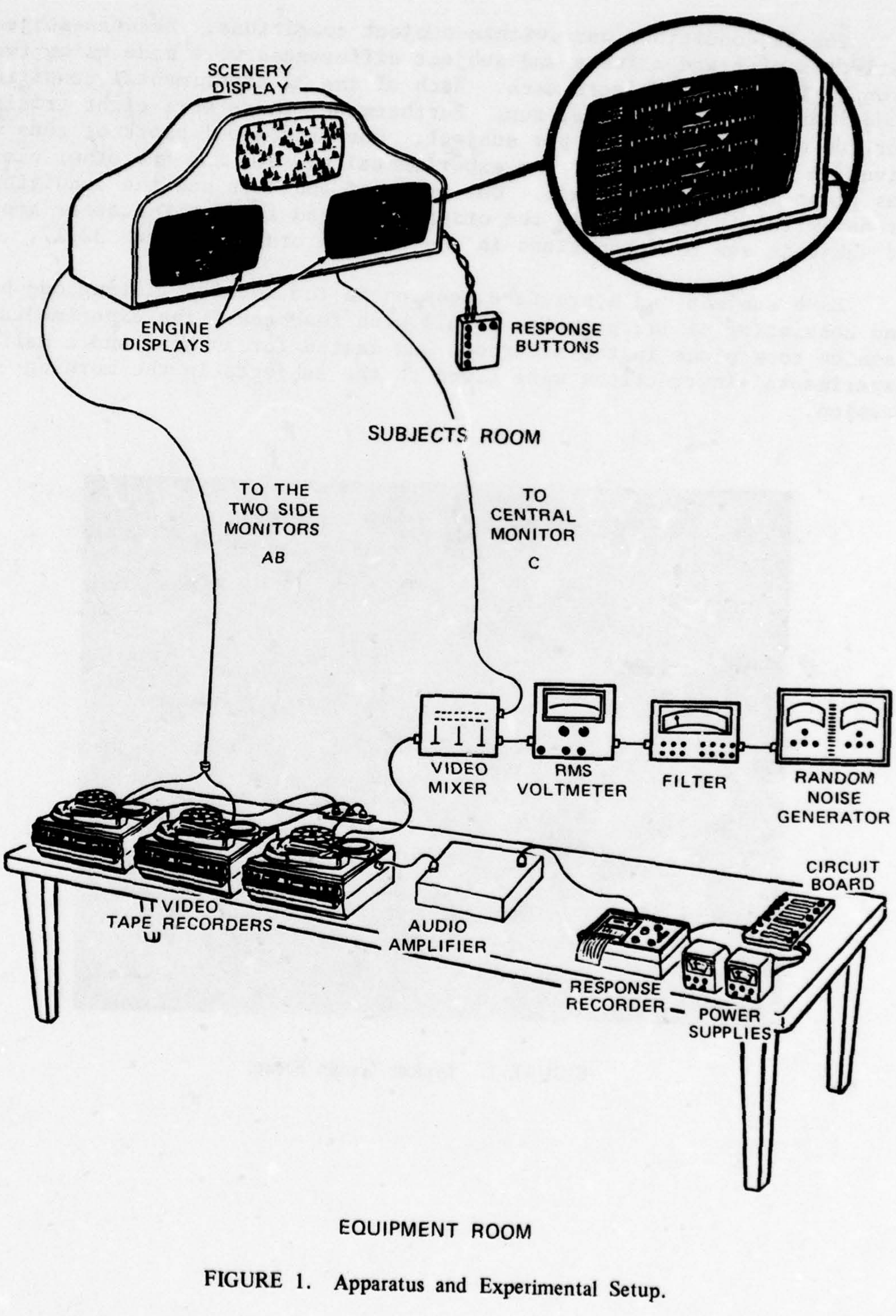

FIGURE 1. Apparatus and Experimental Setup.

The 32 conditions were within-subject conditions. Between-subject estimates of trend effects and subject differences were made using two groups with three subjects each. Each of the 32 experimental conditions constituted an experimental run. Furthermore, there were eight trials per run making 256 trials per subject. One orthogonal block of runs was given in the first half of the experimental session and the other block was given in the second half. One group of subjects saw the conditions (runs) within the blocks in the orders 1-16 and 17-32. The other group of subjects saw the conditions in the reverse order 16-1 and 32-17.

Each subject had a practice session in the morning lasting one hour and consisting of 192 practice trials with feedback. The experimental session took place in the afternoon and lasted for an hour and a half. Experimental instructions were given to the subjects in the morning session.

FIGURE 2. Typical Terrain Scene.

Procedure

The subject sat a premeasured distance from the center monitor with both thumbs on the response box. The run started with the image of a number on the central monitor being replaced by a terrain scene. The run was divided into eight segments (trials) showing different portions of a continuous stretch of terrain simulating 4 nmi. A trial encompassed one terrain segment. After each trial, a tone sounded, indicating the start of the next trial. The tone also signalled the subject to make a forced choice by pressing the YES button if he felt that there was a target in the scene, and pressing the NO button if he felt there was no target in the scene. The forced choice method (i.e., YES-NO response) was used in order to take advantage of statistics developed in signal detection theory. Using these statistics, it is possible to measure the subjects' tendency to miss targets rather than report doubtful (but possible) targets, as well as his ability to detect targets.

The same terrain was viewed for each run. Within each run targets were placed in the middle, left, or right sections of the terrain equally often. However, the placement of targets on any trial was random. Each trial had a 0.50 probability of containing a target. The targets were arranged in a column situated horizontally on the monitor.

Independent Variables

Display size was varied by using either a 2- or a 9-inch TV monitor. Four viewing distances (30, 61, 91, or 183 cm) were used so that visual angle (measured horizontally) could be varied independently of display size.

Simulated airspeed was calculated for the time it would take an airplane to transverse one field of view (FOV), given the fixed parameters in Table 1. Two methods of airspeed simulation were used, depending on the mode of image presentation condition. For the "snow plow" or "moving" mode, the terrain model was moved at a rate of 1 FOV/4 sec and 1 FOV/7 sec, simulating airspeeds of 453 and 259 knots, respectively. In the "series of stills" mode, each scene segment was static, but was replaced immediately at intervals of 4 or 7 seconds by the next scene segment. The tones signalling the subject to make a forced choice were coincident with a change of FOV for both modes of presentation.

The uncertainty (U) of a particular target being present was measured according to Equation 1 in bits.

$$U = \log^2 s \tag{1}$$

where s represents the number of possible targets. Thus, if the subjects were told that any of four targets were possible for a particular run, the uncertainty would be 2 bits.

"Number of targets" refers to the number of targets actually present in a target configuration. Each configuration contained only one type of target. For example, six targets would be a column of six tanks or six trucks, etc.

Because the luminance of the terrain background varied a great deal, the terrain was randomly sampled as to luminance level in the following manner. The four terrain segments used in the experiment were each sampled at eight random locations and the luminances for these 32 locations were averaged to give an average background luminance (BL). The top and bottom of the four targets were each measured with a photometer in the middle of the four terrain scenes and these 32 luminance values were used to find an average target luminance (TL). This was done for both the light and dark targets. The lighter targets were painted with flat earth Pactra enamel (XF-52). The darker targets were painted with Pactra flat dark olive (XF-51) mixed with flat black enamel. The following equation was used to compute this average contrast.

$$\text{Contrast} = \frac{TL - BL}{BL} \tag{2}$$

Both types of target were darker than their backgrounds (i.e., negative contrast) and are referred to as light and dark only to denote the relative appearance of the targets.

The camera was defocused electronically and the resolution measured for both the focused and defocused conditions using a RETMA chart.

Noise was mixed with the VTR signal and measured with an oscilloscope at the output of the mixer[4] to determine signal-to-noise (S/N) ratio. Equation 3 was used to compute the ratio in decibels.

$$\text{S/N ratio} = 20 \log \frac{(\text{peak-peak signal})}{\left(\frac{\text{displayed noise}}{2}\right)} \tag{3}$$

[4] G. Franklin and T. Hatley. "Don't Eyeball Noise," *Electronic Design*, 22 November 1973, pp. 184–187.

Task loading was accomplished by having the subjects monitor two additional TV displays. The displays each presented five gauges showing possible engine malfunctions (average rate: one malfunction per 22 sec). Further details on the malfunction displays are given by Wagner[5] (all monitors in the present experiment were black-and-white). The subject was told to report verbally when one of the indicators on the gauges was out of tolerance. This information was recorded and later compared with the taped malfunctions.

Dependent Variable

The independent measure was the number of correct decisions. The percentage of correct decisions was corrected for chance by subtracting the number wrong from the number correct before computing the proportion correct.[6]

RESULTS AND DISCUSSION

Although the subjects reported that the task was difficult, they performed at an average rate of 69% correct for the detection task over all conditions. For the malfunction reports, all subjects performed at nearly 100% and therefore no further analysis was done on these data.

The effect of the factors was determined by the percentage of the experimental variance each accounted for (i.e., sum of squares (ss) for each factor ÷ total sum of squares). This measure is straightforward and does not require the assumptions that formal testing methods do. Furthermore, it is a measure of the relative importance of the factors, making it a particularly appropriate measure for a screening experiment wherein the main purpose is to choose a subset of the most important variables for further experimentation.

Table 2 gives a breakdown of the sum of squares and percent of variance for the main factors and second-order interactions. Block effects are a measure of within-session learning (first-half performance as opposed to second-half performance). Since the subjects were run in two groups depending on the order in which they observed the experimental conditions, the subject effects were partitioned into subject differences (A) and trend effects (B).

[5] Naval Weapons Center. *Experiments With Color Coding on Television*, by Dan W. Wagner. China Lake, CA, NWC, January 1977. (NWC TP 5952, publication UNCLASSIFIED.)

[6] W. Lee. *Decision Theory and Human Behavior*. New York, John Wiley and Sons, 1971.

TABLE 2. Effect of Main Factors and Strings of Interactions for the Partial Factorial Experiment.

Factor[a]	SS[b]	Percent variance
No. of targets (T)	36	23
Subjects		
(A) Trends	13	8
(B) Differences	7	4
Visual angle (V)	20	12
Signal-to-noise ratio (S)	15	10
Contrast (C)	9	6
No. of tasks (N)	7	4
Blocks	6	4
Resolution (R)	4	2
Display size (D)	2	1
Airspeed (A)	...	...
Presentation mode (M)	...	...
Uncertainty (U)	...	...
D•V	...	...
D•S	...	...
D•M	4	2
V•S	4	2
V•M	7	4
U•C + T•S	...	...
U•S + U•T	...	...
C•R + M•T	2	1
U•N + A•T	...	...
C•S + M•R + A•N + C•T	3	2
M•S + C•R + V•N	5	3
A•S + V•R + C•N	...	...
M•C + R•S + D•N	3	2
V•C + D•R + S•N	...	...
V•S + D•S + N•R + A•M	3	2
V•A + M•U + R•T	...	...
A•U + T•N	...	...
D•M + V•U + D•T	...	...
D•U + V•T	...	...
D•C + V•S + A•R + M•N	...	...

[a] All effects are confounded with higher order interactions. A blank indicates less than 1% of the variance accounted.

[b] Sum of squares.

Figure 3 shows the relative importance of the four most important factors compared with the other factors and second-order interactions. These four factors (i.e., number of targets, visual angle, S/N ratio, and contrast) accounted for 50% of the experimental variance and were chosen for further experimentation. Subject effects also accounted for a significant portion of the variance. Subject differences were analyzed using statistics developed from signal detection theory and are discussed with the results from the second experiment.

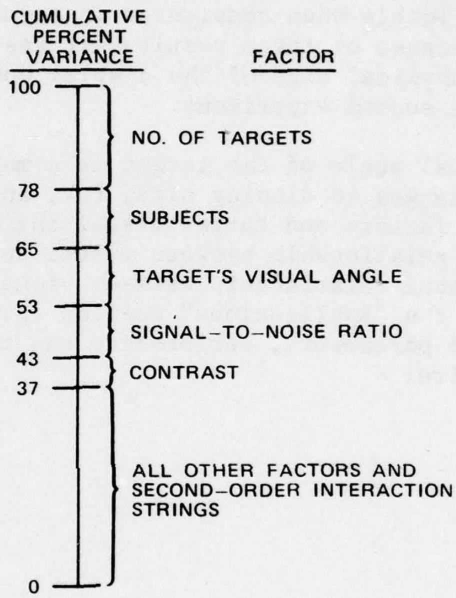

FIGURE 3. Variance Accounted for by Experimental Variables.

It should be noted that, because of the unavoidable confounding involved in using a partial factorial design, Figure 3 should be thought of as a guide to further research rather than an absolute measure of the magnitudes of the various factors used in the screening experiment.[1,2]

Perhaps the most important result of the screening experiment was that the size of the display, independent of the visual angle of the target, was a relatively unimportant factor. Most previous studies have varied the visual angle of the target scene at the same time they varied display size.[7,8] Therefore, it is difficult to tell whether their results are due to the visual angle of the target scene (or targets) or the actual size of the display. Moreover, there is some experimental evidence that performance is improved by viewing a large display at a greater distance than a small display while keeping a constant visual angle.[9,10] The present study and research by Bruns[11] indicate any such improvement is negligible when considered in terms of the total cockpit-display system. Because of these results, it was decided that visual angle and not the physical size of the display would be the parameter of interest for the second experiment.

Also, the visual angle of the target is a more general factor, since it is related to changes in display size, FOV, and range. The relationship between these factors and target visual angle can be used to predict performance if the relationship between visual angle and performance is known. The functional relationship between visual angle and display size is derived in the "Applications" section (p. 23). Given that FOV and range are fixed parameters, performance can then be predicted in terms of display size.

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[7] D. W. Craig and M. L. Hershberger. "Synthetic Aperture Radar Tactical Target Acquisition Research," in *Proceedings of the Human Factors Society, 21st Annual Meeting*, 1977, pp. 244–246.

[8] Rome Air Development Center. *Real-Time Display Parameters Study*, by Marjorie J. Krebs and Carl P. Graf. Griffis Air Force Base, N.Y., RADC, September 1973. (TR-73-300, publication UNCLASSIFIED.)

[9] Naval Training Device Center. *Parameters for Simulation of the Pilot's Real World*, by Halim Ozkaptan. Orlando, FL, NTDC, 1969. (NAVTRADEVCEN Report 68-C-0153-1, publication UNCLASSIFIED.)

[10] A. Chapanis and L. C. Scarpa. "Readability of Dials at Different Distances with Constant Visual Angle," in *HUM. Factors*, Vol. 9 (1967), pp. 38–43.

[11] Pacific Missile Test Center. *Dynamic Target Identification on Television as a Function of Display Size, Viewing Distance and Target Motion Rate*, by R. A. Bruns. Port Mugu, CA, PMTC, 1970. (TP-70-60, publication UNCLASSIFIED.)

EXPERIMENT 2

OVERVIEW

Five factors were examined using a 3x3x3x2x2 full factorial experimental design (Table 3). The data were used to generate a regression model which predicted performance under different levels of visual angle (or display size), number of targets, target configuration, and contrast levels. Applications of the regression model and a correction for the effects of vibration are suggested.

Finally, the results of the two experiments are discussed with emphasis on the appropriateness of the model and a signal detection analysis of subject differences.

TABLE 3. Experiment 2, Fixed Parameters and Independent Variables.

Fixed parameters	Value	Independent variables	Level	Value
Terrain scale	800:1	Visual angle of the target	1	7 min
			2	27 min
Altitude	3,200 ft[a]		3	47 min
Range	2.6 nmi[a]			
Horizontal field of view	2°	Number of targets	1	One
			2	Four
Footprint length	925 m		3	Seven
Footprint width	305 m	Signal-to-noise ratio	1	28 dB
Terrain clutter	(European) medium		2	17 dB
Targets	Tank, truck		3	13 dB
Mode of presentation	Series of stills	Contrast	1	Light (-27%)
Television resolution	300 lines		2	Dark (-48%)
Task load	One	Configuration	1	Linear
Airspeed	363 knots		2	Random
Task	Detection	Dependent Variable	Percent Correct	

[a] Feet and nautical miles, rather than metric terms, are most generally used for altitude and range, respectively.

APPARATUS

The same basic apparatus was used for the second experiment except that there was only one TV monitor (Shibaden, 9-inch diagonal) and a single VTR input.

SUBJECTS

Four of the subjects used in the first experiment, plus two additional subjects, participated in the second experiment. The two additional subjects had been in previous human factors experiments involving the terrain model and had 20/20 corrected binocular vision.

METHODOLOGY

Design

The design was a complete factorial within-subject design. Table 4 shows the within-subject partial counterbalancing scheme for one subject. Each cell was replicated four times for a total of 432 data points per subject. Signal-to-noise ratio and visual angle were completely counterbalanced between subjects. The subjects were given a rest period every 48 trials and a longer rest period every 144 trials.

A morning practice session consisting of 300 practice trials (with feedback) and a 1-hour experimental session the same afternoon were held for each subject.

Procedure

The same basic procedure was used as in the first experiment. The number of trials per run was increased to 16, four of which were of the same experimental condition. The run card starting each run had the number of targets possible printed on it for that run. The durations of the trial and the interval between runs were both 5 seconds. Target placement, type of target, and terrain scenes were counterbalanced within experimental conditions.

Independent Variables

The values of the fixed parameters that were independent variables in the first experiment are presented in Table 3. The values listed in Table 3 for visual angle, number of targets, S/N ratio, and contrast were computed in the same manner as in the first experiment. The viewing

TABLE 4. Experiment 2, Within-Subject Design for One Subject.

FACTOR	VISUAL ANGLE I																																			
S/N RATIO	1												2												3											
NO. TARGETS	A				B				C				B				C				A				C				A				B			
CONTRAST	1		2		1		2		1		2		1		2		1		2		1		2		1		2		1		2		1		2	
CONFIGURATION	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2

FACTOR	VISUAL ANGLE II																																			
S/N RATIO	2												1												3											
NO. TARGETS	B				C				A				C				A				B				A				B				C			
CONTRAST	1		2		1		2		1		2		1		2		1		2		1		2		1		2		1		2		1		2	
CONFIGURATION	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2

FACTOR	VISUAL ANGLE III																																			
S/N RATIO	3												2												1											
NO. TARGETS	C				A				B				A				B				C				B				C				A			
CONTRAST	1		2		1		2		1		2		1		2		1		2		1		2		1		2		1		2		1		2	
CONFIGURATION	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2

distances used to compute the visual angle were 36, 64, and 247 cm. "Configuration" referred to the way in which the targets were aligned. A linear configuration meant that the targets were aligned in a column two target lengths apart and lying along a horizontal line (on the TV monitor). For the random configuration condition, the targets were randomly arranged with adjacent targets being two target lengths apart.

Dependent Variable

The same dependent variable was used in both experiments. In addition, d' and β, measures from signal detection theory, were used to compare subject differences.

RESULTS AND DISCUSSION

Analysis of Variance

Table 5 summarizes the analysis of variance (ANOVA) performed on the data for the second experiment. (The full ANOVA table is given in Appendix B.)

TABLE 5. Experiment 2, Summary of ANOVA.

Factors	F-score	Significance level
Number of targets	47	$P < .01$
Visual angle	40	$P < .01$
Configuration	36	$P < .01$
Contrast	22	$P < .01$
Signal-to-noise ratio	3	NS
Configuration by contrast	11	$P < .05$
Contrast by number	8	$P < .01$
Configuration by contrast by number	13	$P < .01$

The fact that S/N ratio was not a statistically significant factor is somewhat surprising. However, whereas the range of values for number of targets and visual angle was extended for the second experiment (cf. Table 3), the range of values for S/N remained the same as in the screening experiment. At any rate, the data suggest that S/N ratio for the values considered in this experiment is not an important factor.

Figures 4 and 5 show percent correct (corrected for chance[4]) as a function of number of targets and visual angle, respectively. Both figures indicate an increase in performance between the lowest and middle value of these two independent variables. However, the function appears to be asymptotic between the middle and upper values of these factors.

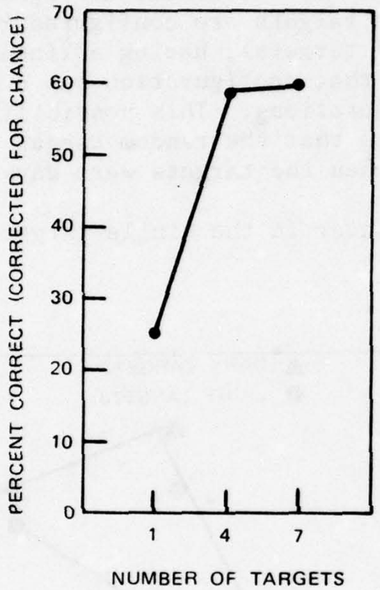

FIGURE 4. Percent Correct as a Function of Number of Targets.

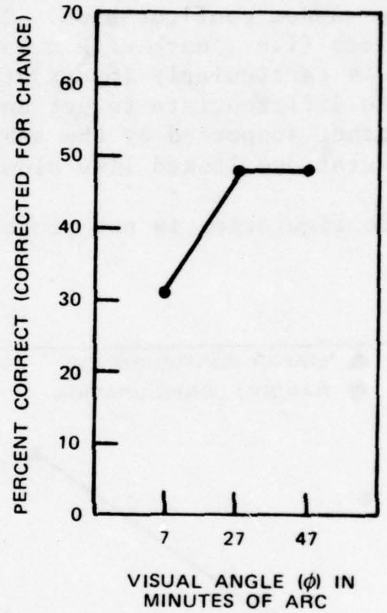

FIGURE 5. Percent Correct as a Function of Visual Angle of Targets.

The interaction between the factors contrast and configuration (Figure 6) is due to the fact that linear configuration only aided performance when the targets were relatively dark. The cause of this seems to be that dark targets were about the same luminance as trees in the terrain scene. When the dark targets were in a linear configuration, they were easily distinguishable from the trees because of their configuration. When these same targets were in a random configuration, the subjects apparently confused the target and tree configurations. Type of configuration was of less consequence for the light targets, because they were not easily confused with trees in the scene.

The same type of explanation seems plausible for the interactions illustrated in Figures 7 and 8. Figure 7 shows that dark targets were most easily detected for the four-target groupings. Since most of the

configurations of the trees in the terrain scene were for groups larger than four, apparently neither the random nor linear configurations of dark targets were easily mistaken for tree configurations when they contained only four targets. The essentially parallel lines in the four-target case shown in Figure 8 support this contention.

However, the seven-target case shows a marked interaction of configuration and contrast (Figure 8). In this case, the dark target conditions show a 35% increase in performance for the linear as opposed to the random configuration. Thus, when the targets are configured like the trees (i.e., dark with a large number of targets), having a linear array is particularly important, suggesting that configuration was a cue used to differentiate target and tree configurations. This possibility is further supported by the subjects' reports that the random target configurations looked like clumps of trees when the targets were dark.

Configuration is not plotted as a parameter in the single-target case.

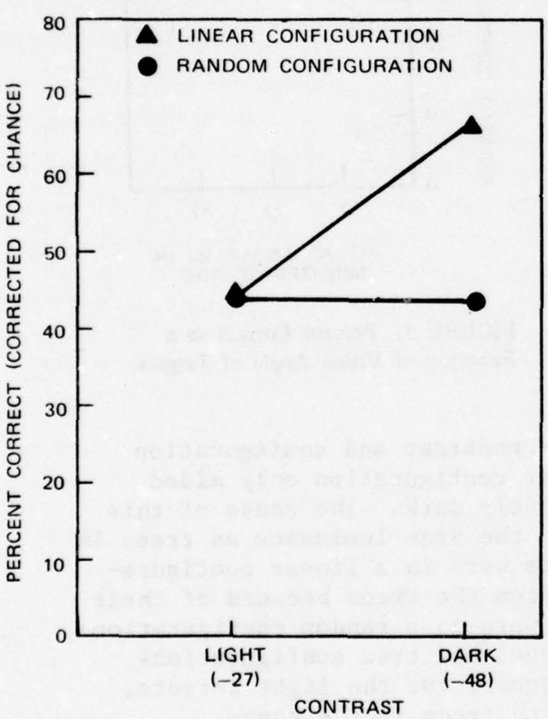

FIGURE 6. Percent Correct as a Function of Contrast With Configuration as a Parameter.

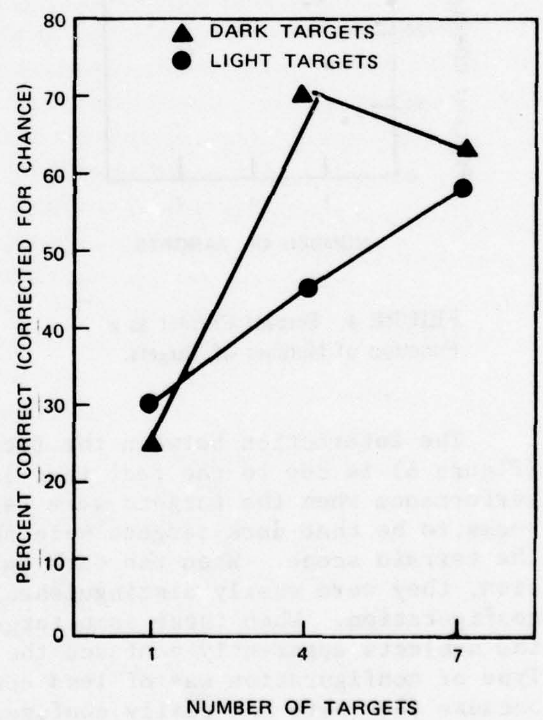

FIGURE 7. Percent Correct as a Function of Number of Targets With Contrast as a Parameter.

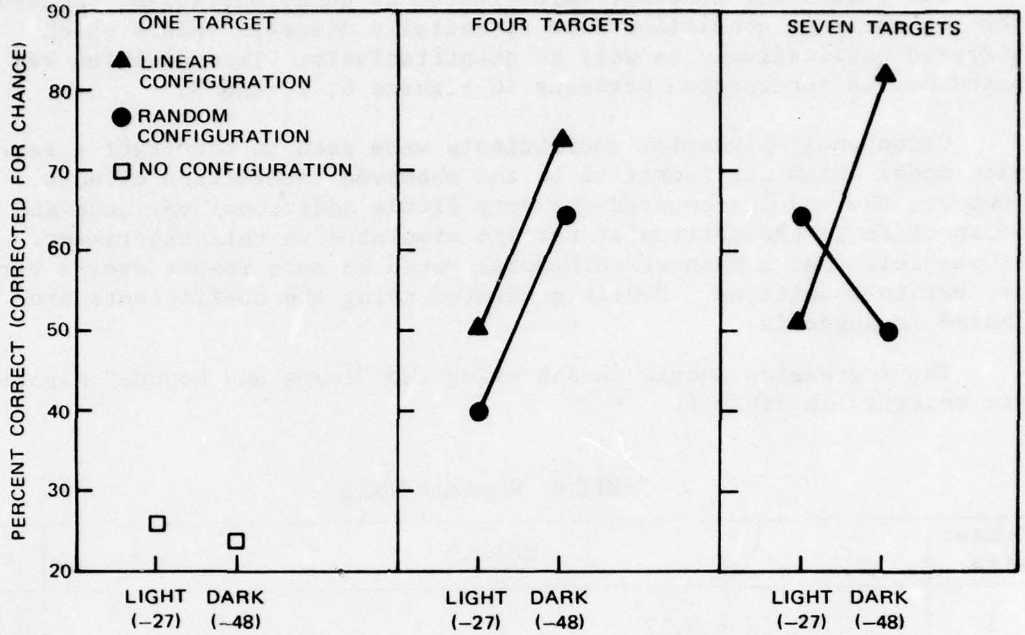

FIGURE 8. Percent Correct as a Function of Contrast With Configuration as a Parameter Plotted for the One-, Four-, and Seven-Target Situations.

Regression Analysis

The data were collapsed over subjects and a regression analysis was done using a "leaps and bounds" regression algorithm.[12] This algorithm chooses the best models for each subset size using the residual sum of squares as a criterion.

Because of the analysis of variance, the independent variables for possible inclusion in the model were modified. The last two levels of the visual angle and number of targets were collapsed. The collapsed models were compared to noncollapsed models using coefficient of determination (r^2) and residual plots[3] to compare the two classes of models. For both criteria, the collapsed models provided a better fit. The collapsed models were used instead of other possible transformations because the data suggested that performance was asymptotic at the middle level for both factors.

[12] G. M. Furnival and R. W. Wilson. "Regression by Leaps and Bounds," *Technometrics*, Vol. 16 (1974), pp. 499–510.

The values for contrast were treated as dummy variables, because the two contrast conditions were essentially discrete values which differed qualitatively as well as quantitatively. This decision was based on the interaction patterns in Figures 6, 7, and 8.

Orthogonal polynomial coefficients were used to construct a regression model which was sensitive to the observed interaction effects. However, the model accounted for very little additional variance and would be specific to the particular terrain simulated in this experiment. It was felt that a main effects model would be more robust over a variety of terrain conditions. Models generated using the coefficients are listed in Appendix C.

The regression models chosen using the "leaps and bounds" algorithm are reported in Table 6.

TABLE 6. Regression Models.

Subset size	Model*	r^{2*}
1	Y = 0.1055N + 0.17	0.32
2	Y = 0.1055N + 0.0098V + 0.165	0.43
3	Y = 0.1055N + 0.0098V - 0.1975C + 0.31	0.47
4	Y = 0.1055N + 0.0098V - 0.1975C + 0.19F - 0.03	0.50
5	Y = 0.1055N + 0.0098V - 0.1975C + 0.19F + 0.05 S/N - 0.13	0.52

* Where

Y = proportion correct decisions corrected for chance
N = number of targets
V = visual angle of target in minutes of arc
C = contrast of target to background
F = configuration of targets
S/N = signal-to-noise ratio
r^2 = coefficient of determination (this is a measure of the amount of variance accounted for).

Configuration and contrast are dummy variables with the following values assigned to their respective levels: 1.0 to linear and light (-0.27); 0.5 to random and dark (-0.48).

APPLICATIONS

LIMITATIONS

Regression models are not meant to show functional relationships among the variables in the system being investigated, but rather to give a best estimate of system performance.[3] The four-term model is the most appropriate model for predictive purposes, since the effect of noise was not found to be statistically reliable in the analysis of variance.

The bounds of the model are important because the models are based on the observed asymptotic functions for the visual angle and number of target terms. Past research[13] indicates that the function relating the operator's performance to the target's visual angle is asymptotic, as was also found in the present experiment. However, it is doubtful that the function relating performance to number of targets is asymptotic beyond the range of values used in this experiment.

With this in mind, the following rules should be observed when using the regression model. First, if the number of targets or visual angle is beyond the asymptotic value found in this experiment, use the asymptotic values of 4 for number of targets and 27 for visual angle. Secondly, if the values of these two factors are beyond the range of the values used in the experiment (seven for number of targets, 47 minutes for visual angle) then the predicted percent detections will be underestimated. A few examples of possible applications for the regression model should help in understanding possible uses of the model in operational and design settings.

OPERATIONAL PREDICTIONS

An analyst wishes to predict the probability of detecting, P(D), a command post (6 targets) at a slant range of 2 nmi from an attack aircraft. He computes the visual angle of an individual target on the display to be about 15 minutes of arc at this range for the imaging device used. The targets are believed to be relatively light and the configuration is random.

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[13] Naval Weapons Center. *Image Identification on Television*, by Ronald Erickson and J. L. Hemingway. China Lake, CA, NWC, September 1973. (NWC TP 5025, publication UNCLASSIFIED.)

$$P(D) = (0.1055(4) + 0.0098(15) - 0.1975(1.0) + 0.19(0.5) - 0.03$$

$$P(D) = 0.44$$

If the analyst has less information, he can use one of the models with less terms listed in Table 7.

PREDICTIONS IN TERMS OF DISPLAY SIZE

The designer is interested in predicting pilot performance under a variety of mission and design conditions. The models in Table 6 can be used to predict performance in terms of display size, because a direct relationship exists between display size and visual angle of the target in the present experiment.

The derivation of this relationship is based on the geometry of the viewing situation. Equation 4 relates the visual angle of the display (α) to the viewing distance (D) and width of the display screen (W) actually used.

$$\tan\left(\frac{\alpha}{2}\right) = \frac{W}{2D} \tag{4}$$

Equation 5 gives the equivalent display size (S) if the distance were kept constant (K) and α were varied.

$$S = 2K \tan\left(\frac{\alpha}{2}\right) = \frac{KW}{D} \tag{5}$$

To solve for S in terms of visual angle of the target (ϕ), it is necessary to know the size of the target (T) imaged on the screen as shown in Equation 6.

$$\tan\left(\frac{\phi}{2}\right) = \frac{T}{2D} \tag{6}$$

Equation 7 solves for ϕ and substitutes the terms S, K, and W from Equation 5 into Equation 6.

$$\phi = 2 \tan^{-1}\left(\frac{ST}{2KW}\right) \tag{7}$$

For the present experiment, T equals 0.2 inch, W equals 7 inches, and the pilot is assumed to be 25 inches (K) from the screen. Equation 7 gives a solution of ϕ in terms of S or $\phi = 2 \tan^{-1} (0.000562)$ S. This solution is in degrees, to solve for ϕ in minutes of arc, $\phi = 120 \tan^{-1} (0.000562)$.

As an example, the designer wishes to predict probability of detection as a function of display size (for a situation that is comparable to the simulation parameters listed in Table 3). He is also interested in the effect of target contrast and the one target versus the multitarget (4 to 7) situation. Assuming that the pilot sits 25 inches from the display, $120 \tan^{-1} (0.000562)$ (display size) can be used instead of visual angle of the target as the predictor variable in the regression equation (in this case, the three-term model in Table 6). Figure 9 shows the predicted percent correct detections in this case.

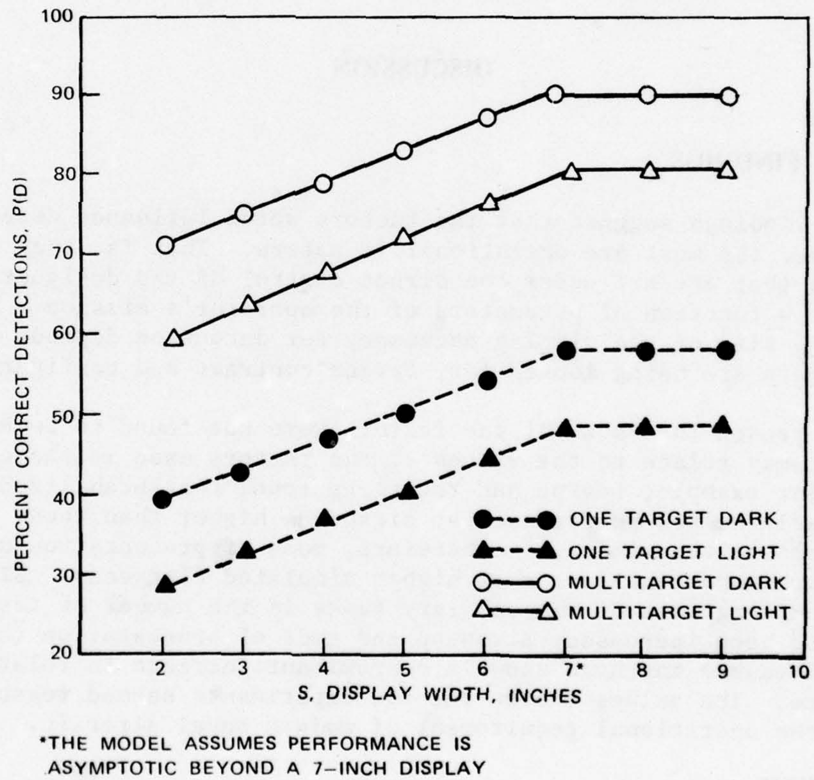

FIGURE 9. Predicted Detection Performance Using the Regression Model With Display Size, Number of Targets, and Target Contrast as Terms.

CORRECTIONS FOR VIBRATION

Obviously, the reliability of the predictions from the regression models depends on how well the simulation parameters reflect the real-world situation. It is possible to correct P(D) for variables not included in the model, provided the correction factor is known and the new variables do not interact with the variables included in the model.

As an example, Figure 10 shows curves of equal decrement of performance (percentage correct) plotted against acceleration and frequency of vibratory stimuli.[14] These curves can only be used as approximate correction factors, since the task used was a number reading task. However, there is little reason to believe that vibration interacts with the factors included in the regression models and a ball park estimate of the effects of vibration is advisable in making any realistic estimate of system performance for Naval aircraft.

DISCUSSION

GENERAL FINDINGS

The findings suggest that the factors which influence detection performance the most are operational in nature. That is, they are variables that are not under the direct control of the designer but change as a function of parameters of the operator's mission. Specifically, the size of the display necessary for detection depends on how many targets are being looked for, target contrast and configuration.

One reason that some of the factors were not found to be more important may relate to the values of the factors used in the experiments. For example, Levine and Youngling found that stabilized images particularly helped performance at airspeeds higher than those simulated in the present experiment.[15] Therefore, mode of presentation may have been a more important factor at higher simulated airspeeds. Similarly, if the sampling rate of the auxilary tasks in the number of tasks condition had been increased, airspeed and mode of presentation (as well as number of tasks) may have shown a concomitant increase in relative importance. The values chosen for the experiments seemed reasonable in view of the operational requirement of modern Naval aircraft.

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[14] S. J. Morrissey and A. C. Bittner. "Effects of Vibrations on Humans: Performance Decrements and Limits," in *Proceedings of the Human Factors Society*, 1977, pp. 68–72.

[15] McDonnell Douglas Astronautics Company, East. *Real Time Target Acquisition with Moving and Stabilized Image Displays*, by S. H. Levine and E. W. Youngling. St. Louis, MO, MDC, 1973. (MDC E0769, publication UNCLASSIFIED.)

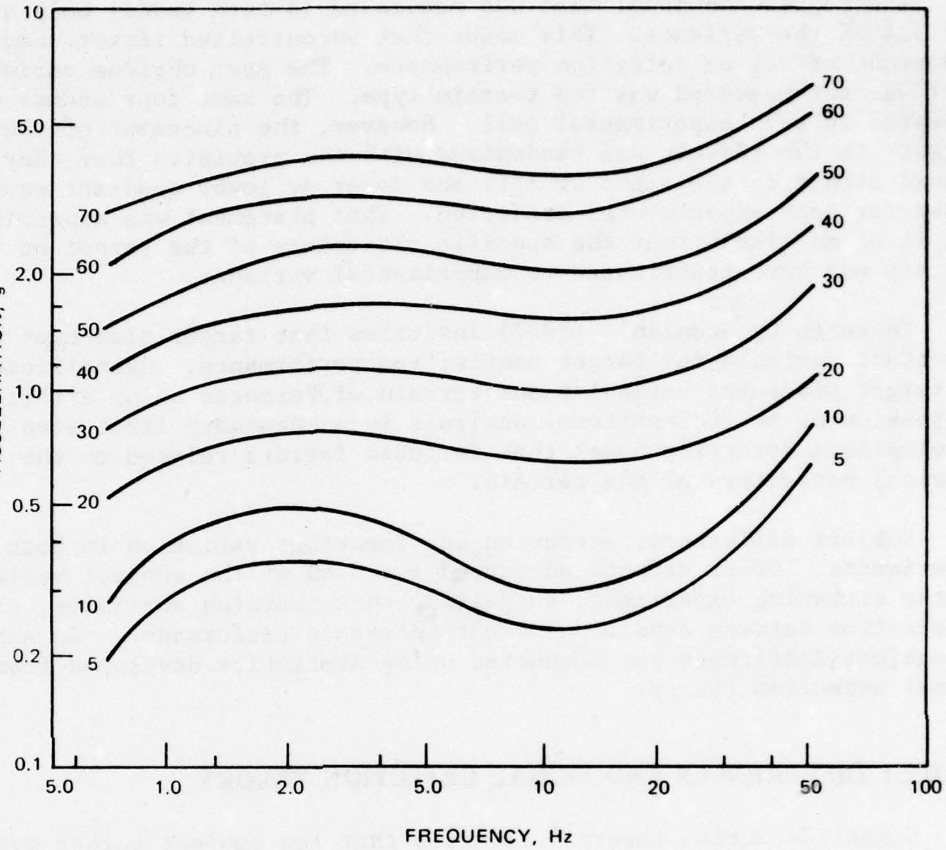

FIGURE 10. Isodecrement Curves (Percent Correct) Plotted Against Acceleration and Frequency of Vibratory Stimuli (Morrissey and Bittner, 1977).

Another reason some factors were not shown to be important may be the specific task used in the experimental situations. Signal-to-noise ratio and resolution, for the values in the present experiment, affect detail rather than overall shape of both the target and background. Detection depends on the general energy level or shape of the targets, whereas recognition and classification depend on specific features.[16] Thus, S/N ratio and resolution could be expected to have a greater impact on recognition and classification performance than on detection performance. Also, the subject's cognitive uncertainty was unrelated to detection performance, although past research indicates it does affect classification performance.[16]

[16] W. G. Garner. *The Processing of Information and Structure*. Potomac, MD, Lawrence Erlbaum Associates, 1974.

The regression model that was generated (4-term model) only accounts for 50% of the variance. This means that uncontrolled factors had an important effect on detection performance. The most obvious variable that was not measured was the terrain type. The same four scenes were repeated in each experimental cell. However, the placement of the targets in the terrain was randomized with the provision that they were placed either to the right or left and upper or lower quadrant equally often for each experimental condition. This placement was approximate and it seems likely that the specific placements of the target on the terrain may have contributed to experimental variance.

Research by Scanlan[17] (1977) indicates that target placement is an important variable for target acquisition performance. Quantification of target placement variables and terrain differences using either regression or multidimensional analysis is a necessary first step in developing a detection model that includes factors related to the physical parameters of the terrain.

Subject differences accounted for important variation in both experiments. Order effects accounted for 0.60 of the subject variation in the screening experiment, suggesting that learning variables, or interaction between conditions might influence performance. An analysis of subject difference was conducted using statistics developed from signal detection theory.

SUBJECT DIFFERENCES AND SIGNAL DETECTION THEORY

Signal detection theory[18] requires that the subject gather evidence concerning two alternatives and compute the odds concerning their relative veracity. β is the criterion the subject uses to make his decision. If the odds are above (or equal to) β he chooses one alternative and if they are below β he chooses the other alternative.

For psychophysical experiments, the alternatives are considered to be, (1) noise and (2) signal with noise.[18] In the present experimental paradigm, these alternatives were represented by trials with (1) terrain scenes alone, and (2) the scene with a target located somewhere in it. d' is a measure of the subject's ability to differentiate between the two alternatives (i.e., his sensory sensitivity) and is independent of the subject's β (i.e., his decision strategy).

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[17] L. W. Scanlan, "Target Acquisition in Realistic Terrain," in *Proceedings of the Human Factors Society*, 1977, p. 249.

[18] D. M. Green and J. A. Swets. *Signal Detection Theory and Psychophysics*. New York, John Wiley and Sons, 1964.

Performance depends on both d' and β. There is an optimal β depending on the prior probability of the targets and the utility of choosing one alternative over the other. In the present experiments, the subjects were informed that both the prior probability and utility of saying "yes" or "no" (as to whether a terrain scene contained a target) were equal. In this particular case, the optimal β is one (odds are 1 to 1) and if the subject's decision strategy favors either alternative his percent detection score will be affected adversely.

An estimate of the subjects' d' and β were made for both experiments and used to analyze subject differences (Table 7).

TABLE 7. Signal Detection Analysis of Subject Differences.

Subject	Probability of detection, P(D)[a]	d'	β
A. Experiment 1			
1	.66	2.16	2.78
2	.70	2.08	0.84
3	.80	2.78	2.83
4	.73	2.38	2.94
5	.62	1.90	2.11
6	.54	1.56	1.86
B. Experiment 2			
1	.37 (6)[b]	1.15 (6)[b]	2.13 (3)[b]
2	.50 (5)	1.70 (3)	3.31 (5)
3	.53 (3)	1.82 (1)	3.33 (6)
4	.54 (2)	1.73 (2)	2.54 (4)
5	.48 (4)	1.40 (5)	2.00 (2)
6	.54 (1)	1.47 (4)	1.65 (1)

[a] Corrected for chance.
[b] Numbers in parentheses indicate rank.

In the first experiment, most of the subjects favored missing targets rather than committing errors of false detection, which was indicated by a β of 2 or 3. Subject 2 had a β close to 1 (nearly optimal). His measured sensory sensitivity (d') was lower than that of subject 1 but his probability of detection, P(D), was better. In other words, he apparently saw* fewer targets than subject 1, but was able to maximize his P(D) by using an optimal decision strategy.

* In the sense that clutter and targets were not as easily differentiated.

The effect of decision strategy is more marked in the second experiment. Subjects were even more disposed toward missing targets as opposed to making false detections. Subject 1 had the best P(D) score (although only minimally better than subject 3 or 4), but his d' score ranked fourth, whereas his β was the closest to optimal. This means that in relation to the other subjects his ability to detect the target was poor but his decision strategy was good. His d' score was 23% less than that of subject 3, but his P(D) was slightly better. In general, the subject's rank for P(D) and d' are not well correlated, suggesting that the subject's P(D) scores are due to decision strategy as well as sensory sensitivity.

These results are more suggestive than conclusive, since in terms of absolute magnitude the effects are small. However, the experimental situation did not manipulate factors which traditionally[18] affect decision strategy and the optimal strategy was emphasized to the subjects. The effect of decision strategy on detection performance should be investigated under conditions more like actual operational settings (i.e., different probabilities and utilities for events to occur). If P(D) is a result of β as well as d', different design strategies are called for. For example, P(D) might improve more by giving the pilot realistic prior probabilities for target occurrence rather than increasing the display size.

SUMMARY

1. The physical size of the display (when MTF and visual angle were controlled) proved to be a relatively unimportant factor in the screening experiment.

2. Most of the factors that were included in the regression model (number of targets, target contrast, and target configuration) were operational factors rather than design parameters.

3. Derivation of the relationship between the visual angle of the target and display size allowed performance to be predicted in terms of display size.

4. Configuration cues such as linearity and number of targets interacted with target contrast, suggesting a complex relationship between these factors and terrain parameters.

5. Most subjects were non-optimal in their decision strategy (β) (i.e., they were willing to miss many potential targets rather than make false detections). Differences in decision strategies (β) were as important as differences in sensory processing abilities (d') in explaining performance differences among subjects.

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Appendix A

ENGINEER'S REPORT ON DISPLAY PERFORMANCE MATCHING

by Richard Hensley

The display size experiment conducted by the Human Factors Branch, Code 3175, required that two displays of different screen size have equal performance. The following is a discussion of how the performance of two displays was measured and matched.

The two displays chosen for the experiment were a 9-inch Conrac and a 3-inch 3Q. The measure of performance used against the two displays was the Modulation Transfer Function (MTF). MTF is the Fourier transform of the display's rise time response from a black to white edge transition. With matched MTF, the displays will respond equally to a given input.

The measurement of MTF was accomplished by utilizing a scanning microphotometer. The microphotometer scanned the black to white edge transition, measuring light amplitude as a function of distance across the scene. Figure A-1 is a block diagram of the measurement process. Table A-1 is an equipment list.

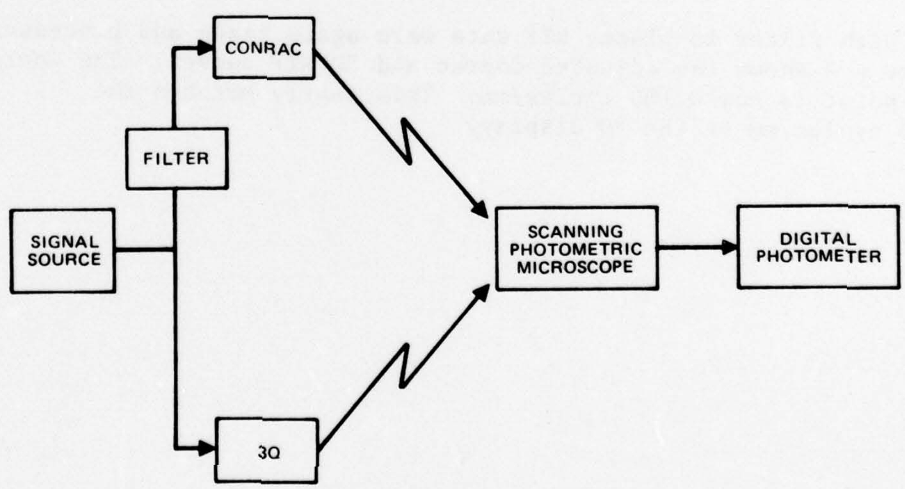

FIGURE A-1. MTF Measurement Block Diagram.

TABLE A-1. MTF Measurement Equipment.

Signal source	Visual Information Institute Model 508 CCTV Signal Source
Photometric microscope	Gamma Science, Inc. Model 700-10A
Digital photometer	Gamma Science, Inc. Model 2400

The data from the scanning photometer were then processed by a Wang 2200 programmed for doing Fourier transforms. Figure A-2 shows the MTF curves for both displays.

The Conrac display had significantly better performance than the 3Q display. The Conrac display was 3 dB (0.707 amplitude) down at 0.45 cycles/mm. The 3Q display was 3 dB down at 0.17 cycles/mm. The Conrac performance must be reduced to match that of the 3Q.

The performance of the Conrac was reduced by adjusting the brightness and contrast controls. However, brightness and contrast could not reduce the performance enough to match the 3Q. The brightness and contrast controls were returned to a setting near that of the 3Q. A single pole, RC low-pass filter having a time constant, T, of 0.28 μsec was then inserted at the input of the Conrac display. Figure A-3 is the measured frequency response of this filter.

With filter in place, MTF data were again taken and processed. Figure A-4 shows the adjusted Conrac and 3Q MTF curves. The Conrac 3-dB point is now 0.180 cycles/mm. This nearly matches the 0.170 cycles/mm of the 3Q display.

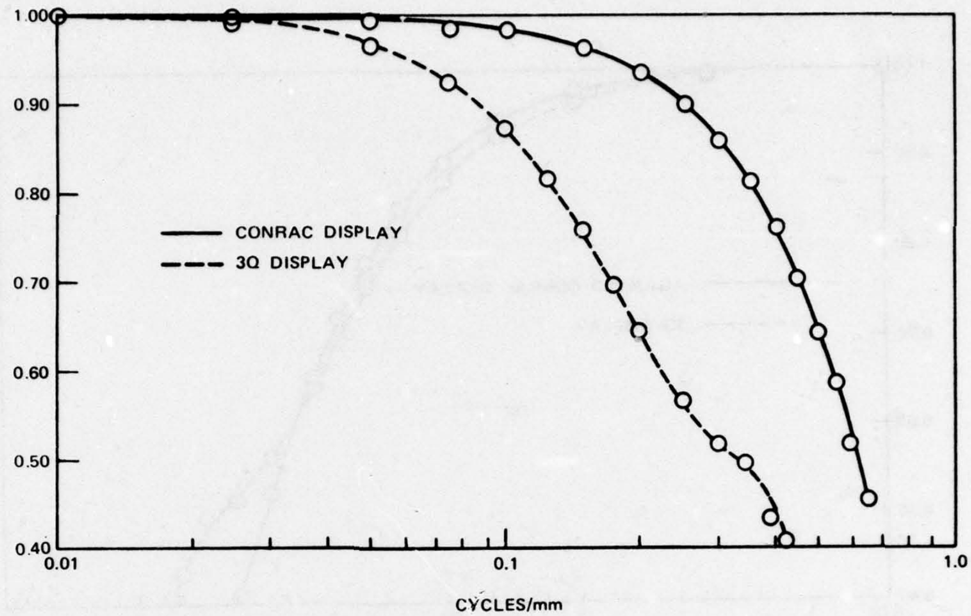

FIGURE A-2. Display MTF Curves.

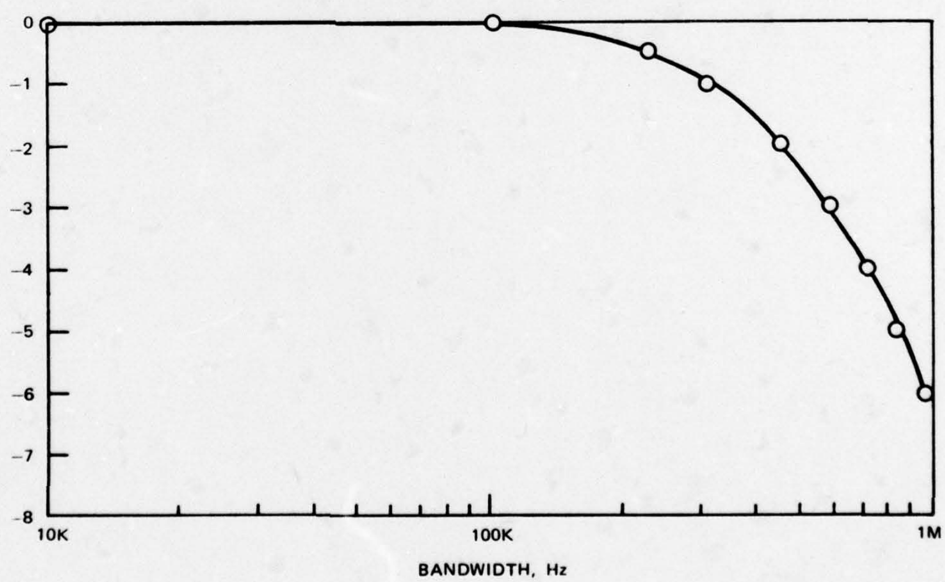

FIGURE A-3. In-Line Filter Schematic and Bandwidth.

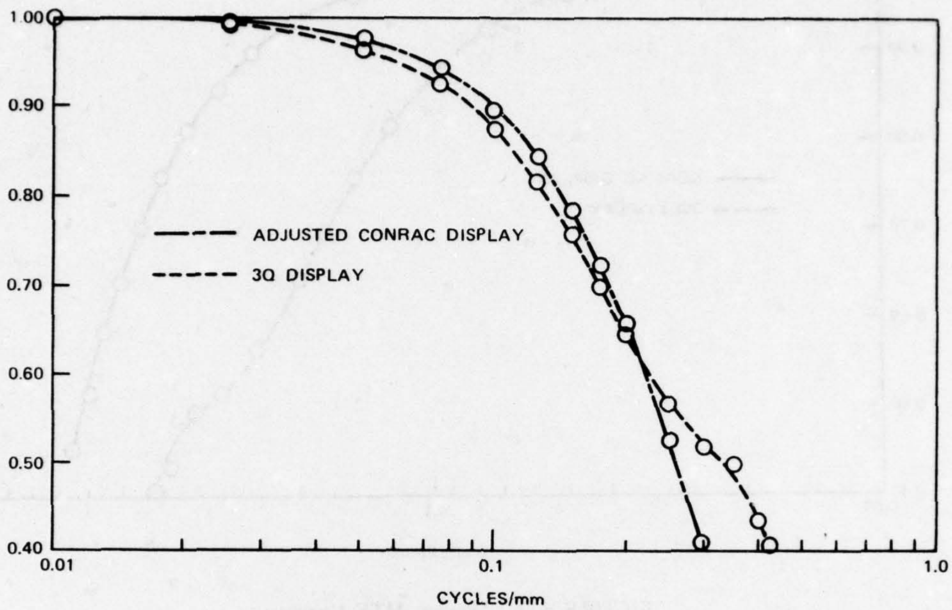

FIGURE A-4. Matched MTF Curves.

Appendix B

EXPERIMENTAL DESIGN AND RESULTS

Experimental conditions for the partial factorial experiment.

Code	Factor	High value	Low value
A	Display size	9	2
B	Visual angle	22 min	11 min
C	Airspeed	460 knots	259 knots
D	Mode of presentation	Snow plow	Stills
E	Uncertainty	1 bit	2 bits
F	Contrast	-.48	-.27
G	S/N	28 dB	12 dB
H	Resolution	300 lines	175 lines
I	No. of tasks	One	Three
J	No. of targets	Six	Three

Experimental (runs) conditions: Letter means that high value of that factor is used for that condition, low value assumed otherwise.

Block I: Basic		Block II: Fold over	
Cond	High value factors	Cond	High value factors
1	ABCDEFGHIJ	17	All low values
2	ABDH	18	CEFGIJ
3	ACEFH	19	BDGIJ
4	AGHIJ	20	BCDEF
5	ACDGJ	21	BEFIH
6	ABCI	22	DEFGHJ
7	ABEFGJ	23	CDHI
8	ACEFI	24	BCGHJ
9	BECGH	25	ADEIJ
10	BFHIJ	26	ACEGD
11	DFGH	27	ABCEIJ
12	CDEHIJ	28	ABFG
13	EJ	29	ABCDFGHI
14	EFGI	30	ABCDHJ
15	BDEGI	31	ACFHJ
16	BCDFG	32	AEHI

ANOVA TABLE (Display Size: Experiment 2).

Error term is the next higher order interaction which includes only the factor(s) to be tested and subjects (F).

F Score only given for statistically significant factors and interactions.

Factor*	MS[a]	DF[b]	F Score[c]	α[d]	Factor*	MS[a]	DF[b]	F Score[c]	α[d]
A	6.52	1	36	0.01	ABF	0.58	5	...	...
B	6.125	1	22	0.01	ACF	0.39	10	...	...
C	30.19	2	47	0.01	BCF	0.48	10	...	...
D	2.24	2	..	...	ADF	0.46	10	...	...
E	11.31	2	40	0.01	BDF	0.38	10	...	...
F	1.66	5	...	...	CDF	0.53	20	...	...
AB	6.52	1	11	0.05	AEF	1.64	10	...	...
AC	0.04	2	...	...	BEF	0.35	10	...	...
BC	3.97	2	8	0.01	CEF	0.852	20	...	...
AD	0.10	2	...	...	DEF	0.800	20	...	...
BC	0.197	2	...	...	ABCD	0.37	4	...	...
BD	0.199	2	...	...	ABCE	1.28	4	...	...
CD	0.428	4	...	...	ABDE	0.30	4	...	...
AE	0.168	2	...	...	ACDE	0.64	8	...	...
BE	0.81	2	...	...	BCDE	1.54	8	...	...
CE	0.129	4	...	...	ABCF	0.283	10	...	...
DE	0.235	4	...	...	ABDF	0.52	10	...	...
AF	0.183	5	...	...	ACDF	0.55	20	...	...
BF	0.284	5	...	...	BCDF	0.55	20	...	...
CF	0.64	10	...	...	ABEF	0.58	10	...	...
DF	0.54	10	...	...	ACEF	0.46	20	...	...
EF	0.28	10	...	...	BCEF	0.65	20	...	...
ABC	3.65	2	13	0.01	ADEF	0.86	20	...	...
ABD	0.14	2	...	...	BDEF	0.62	20	...	...
ACD	0.29	4	...	...	CDEF	0.68	40	...	...
BCD	0.27	4	...	...	ABCDE	1.94	8	...	...
ABE	0.29	2	...	...	ABCDF	0.52	20	...	...
ACE	0.39	4	...	...	ABCEF	0.49	20	...	...
BCE	1.37	4	...	...	ABDEF	0.81	20	...	...
ADE	0.467	4	...	...	ACDEF	0.77	40	...	...
BDE	0.21	4	...	...	BCDEF	0.38	40	...	...
CDE	1.43	8	...	...	ABCDEF	0.87	40	...	...

* Factors: A = Alignment; B = Contrast; C = Number of targets; D = Signal-to-noise ratio; E = Target visual angle; F = Subject.

[a] MS = mean squares; [b] DF = degrees of freedom; [c] F Score = MS factor ÷ MS error term; [d] α = significance level.

Appendix C

REGRESSION MODELS USING ORTHOGONAL POLYNOMIAL COEFFICIENTS

Variable	Symbol	B weight	B_i	Coefficient coding					
				Level 1	Code	Level 2	Code	Level 3	Code
No. of targets	N	0.1676	B_1	1	-1	4	0	7	1
(No. of targets)^2	N^2	-0.0435	B_2	1	1	4	-2	7	1
Contrast	C	-0.0494	B_3	-0.48	-1	-0.27	1	...	...
Configuration	F	0.048	B_4	random	-1	linear	1	...	...
Signal-noise	S/N	0.051	B_5	13	-1	17	0	28	1
Contrast by configuration	CF	-0.0495	B_6	...	...	...	...	...	...
No. targets by contrast	NC	-0.0397	B_7	...	...	...	...	...	...
Contrast by configuration by No. of targets	NCF	-0.0408	B_8	...	...	...	...	...	...
Visual angle	V	0.195	B_9	7	-1	27	0	47	1
Intercept	A	1.98	B_0	...	...	...	...	...	...

Subset size	Best fit models	r^2
1	$Y = B_1N + B_0$	26
2	$Y = B_1N + B_9V + B_0$	38
3	$Y = B_1N + B_9V + B_2N^2 + B_0$	43
4	$Y = B_1N + B_9V + B_2N^2 + B_6CF + B_0$	47
5	$Y = B_1N + B_9V + B_2N^2 + B_6CF + B_3C + B_0$	50
6	$Y = B_1N + B_9V + B_2N^2 + B_6CF + B_3C + B_4F + B_0$	54
7	$Y = B_1N + B_9V + B_2N^2 + B_6CF + B_3C + B_4F + B_5S/N + B_0$	56
8	$Y = B_1N + B_9V + B_2N^2 + B_6CF + B_3C + B_4F + B_5S/N + B_8NCF + B_0$	57
9	$Y = B_1N + B_9V + B_2N^2 + B_6CF + B_3C + B_4F + B_5S/N + B_8NCF + B_7NC + B_0$	58

INSTRUCTIONS: EXPERIMENT 1

This is a simulated reconnaissance mission. Your task will be to detect possible targets: missiles, tanks, houses, or trucks. These targets are displayed on the table in front of you and will either be fairly light (the tan ones) or dark (dark gray ones). The targets will be displayed in groups of from three to six. You don't have to identify what the targets are. Rather your task will be to detect possible target configurations. You will be told what targets are possible before each run.

We will move over to the simulated display. This is the response box, hold it so it is comfortable. The TV monitor I am pointing at is the display the simulated terrain will be imaged on. First you will see a card with a number on it. A few seconds after this an image of the terrain will replace the card.

Next, a buzzer will sound initiating the first trial. This will signal you to look at the terrain carefully for a possible target.

When the second buzzer sounds, you will make a forced choice by pressing the "yes" button, if there had been a target since the previous buzzer; otherwise press the "no" button. There will be nine buzzers for each experimental run. You will ignore the first buzzer and respond to each of the next eight buzzers. Respond as quickly as possible to each buzzer since you will be timed.

Again, do not respond to the first buzzer, but for each successive buzzer decide whether you detected a possible target configuration since the previous buzzer and respond as quickly as you can.

There are two possible modes of presentation. One mode will consist of still images of the terrain which will replace each other right after the buzzer sounds. The target can be any place on the image for this mode. In the other mode, the terrain will be moving through your television screen. Immediately after the buzzer ending one trial, targets for the next trial will come into your field of view for trials in which the targets are present. In this mode, the best strategy is to fixate on a place near the top of the screen and search the horizontal plane because the targets will pass through this point, if they are present for that trial. Approximately half the trials will contain targets. That is, there is a 50-50 chance that a target will be present for a particular trial. Missing targets on trials where there was one will count against you as much as saying there was a target for trials in which there was no target.

There will be five gauges on each screen. A gauge indicator will move back and forth. If the indicator stays in tolerance, it will stay in the light portion of the display. When it goes out of the light portion and turns dark, it is out of tolerance. You will indicate whether it is out of tolerance by noting whether display A or B is out of tolerance, and also the direction left or right. For example you might say "screen A, left" indicating that the display marked A is out of tolerance to the left.

Are there any questions? We will run through a number of practice trials, if you have any questions be sure to clear them up during the practice session.

INSTRUCTIONS: EXPERIMENT 2

The experiment will consist of a simulated reconnaissance mission. Your mission will be to detect possible target configurations. It is not necessary to identify possible targets. Rather, you will report possible target configurations. For the practice session, tanks, houses, or trucks will be possible target configurations. In the experimental session, only tanks or trucks are possible targets. Over here on the terrain model are examples of possible target configurations. The configurations will vary from one to seven targets. They will be in a straight line or randomly dispersed and will be either light or dark. Let's go over to the mock display and sit in front of the experimental monitor. The headrest will keep you the proper distance from the display, keep your forehead flush on the rest. This is your response box. The monitor in front of you will simulate a ground-stabilized imaging device found in aircraft. You will see a still picture of terrain lasting 5 seconds. These images of the terrain will be replaced by pictures of the terrain every 5 seconds. A tone will signal the end of a scene's duration. When you hear the tone you must make a decision whether a possible target configuration was present or absent in the terrain scene just ending. If you decide that a target configuration was present press the "yes" button, and if you decide that the scene did not contain a configuration press the "no" button.

Remember that, under some conditions, it will be very difficult to decide whether a target is present or whether what you are looking at is terrain clutter. You must use your best judgment and respond to the tone at the end of each scene. Responding no when targets are present will influence your score as much as responding yes to scenes in which targets are absent. Over the whole experiment half the scenes you will see will have targets and half will not. The time between tones (that is, the duration of one scene) will constitute one trial. A trial will take 5 seconds. (Show Briefing card.)

A target run will consist of 16 trials. There will be 27 runs. At the beginning of each run a card will indicate the run number and inform you the number of targets to look for in the upcoming run.

Every three runs, the word change will be added to the card starting the run. The experimenter will give you about a minute rest. After nine runs you will get a 5-minute break. An experimental session will take approximately an hour.

For the rest of the morning session, you will run practice trials. I will show you the targets for the first block of runs, then you will run through the block yourself and I will give you feedback concerning performance. You will then run two additional blocks of runs under more difficult conditions. During the practice session, you may interrupt anytime to ask questions. Do you have any questions about the instructions?

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